Estimation of radiographic angles and distances in coronal part of mandibular molars: A study of panoramic radiographs using EMAGO software

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ABSTRACT

Objective: This study was designed to investigate radiographically the effects of age and external irritating stimuli on the morphology and thickness of the pulp chamber ceiling and floor in mandibular molars. **Materials and Methods:** A total of 234 panoramic radiographs were recruited and 494 mandibular molars were examined in this study. The sample was divided into six age groups: Group 1, <20 years; Group 2, 20-29 years; Group 3, 30-39 years; Group 4, 40-49 years; Group 5, 50-59 years and Group 6, >60 years. Each group was subdivided into two subgroups with regard to the tooth condition (intact or non-intact teeth). Four distances, two angles and two ratios were measured, in order to estimate the dimensions of the pulp chamber and the thickness of the pulp chamber ceiling and floor. **Results:** The thickness of the pulp chamber ceiling and floor increased significantly from Group 1 to 6. The pulp chamber floor angle presented progressive sharpness from Group 1 to 6 whereas the pulp chamber ceiling angle presented progressive bluntness from Group 1 to 5 and sharpness from Group 5 to 6. Significant differences were identified in the thickness of the pulp chamber ceiling, the thickness of the pulp chamber floor and the ceiling-floor distance between intact and non-intact teeth. **Conclusion:** Based on those results, there are differences in the location of secondary dentin formation between the two pulp chamber walls. Age is related to diminished pulp chamber size. The increase rate of the pulp chamber ceiling thickness is similar to that of the pulp chamber floor thickness. Furthermore, external irritating stimuli have an effect on the pulp chamber dimensional changes.

Key words: Angles, EMAGO, molars, panoramic radiographs

INTRODUCTION

In clinical practice, it is essential to preserve the pulp vitality during restorative procedures in order to avoid postoperative endodontic complications. Iatrogenic pulp exposure compromises pulpal health and increases the risk for pulp necrosis. In addition, iatrogenic errors should be avoided during endodontic treatment. Diffuse calcification of the pulp chamber increases the risk of iatrogenic furcal perforations upon access. Accidental furcal perforations during endodontic access have unpredictable healing, impairing the tooth prognosis.[1] For these reasons, it is imperative to define external anatomical key landmarks and relate the external dimensions of the crown to the morphology of the pulp chamber.

The first radiographic research was carried out in 1961 in order to give information on the pulp chamber size.[2] Little information is revealed in the dental literature on the relationship between the pulp chamber floor and the furcation for the posterior teeth. The distance from the pulp chamber floor to the furcation root surface was found to a range from 2.7 to 3.0 mm for both mandibular and maxillary molars.[3] In another study, the mean distance from the floor of the pulp

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chamber to the root furcation surface was found to be equal or less than 3.0 mm for the maxillary molars.[4] More recently, the same distance was found to be 3.05 mm for the maxillary molars and 2.96 mm for the mandibular molars.[5]

However, the dimensions of the pulp chamber and the thickness of the pulp chamber walls can change with age. During aging the pulp chamber size is gradually reduced because of deposition of dentin on all internal walls of the pulp cavity.[2] The rate of dentin formation varies among the pulp chamber walls.[2] Secondary dentin is formed after tooth eruption and is the result of advancing age. Tertiary dentin is formed in response to irritating stimuli such as caries, restorative materials, cavity preparation and occlusal wear. The aggressive invasion of carious lesions into dentin causes the formation of a new layer of dentin in continuation with the primary or secondary dentin. Underneath this dentinal layer, the pulp tissue has the chance to retreat.[6-8]

The coronal pulp size and the effect of restoration procedures on the pulp chamber size and the height of the pulp horns in human first molars were studied by Chandler *et al*.[9] The reduction in pulp horn heights by restorations was found to vary between 11% and 22%.[9] A reduction in the height of the pulp chamber of mandibular first permanent molars by 15% was detected over a 3 year period.[10] Although there was no difference between the pulp size of intact and restored teeth, carious teeth presented a trend for diminution in the width of the pulp chamber.[10] According to other studies, age is much more important than any abnormal factor in dentin formation.[2,11]

This study aimed to investigate the effects of age and external irritating stimuli on the morphology and thickness of the pulp chamber ceiling and floor in first and second mandibular molars.

According to studies and knowledge on the formation of secondary dentin, a rational hypothesis would be the homogeneous deposition of a secondary dentin layer on both the floor and the ceiling of the pulp chamber with age or after irritating stimuli on the tooth.

MATERIALS AND METHODS

A total of 234 panoramic radiographs were recruited from School of Dentistry, University of Athens. Ethical approval was obtained from the University of Athens Dental School Committee for Research Ethics (Research Protocol #172A, 2011). 494 mandibular molars (262 first and 232 s molars) were used in this study. The sample included only first and second mandibular molars as the pulp chamber margins and the external key morphological landmarks were distinguishable enough in those tooth types to allow for safe and precise measurements. All panoramic radiographs were taken by the same panoramic X-ray unit (Planmeca ProMax, Helsinki, Finland) and digitized by the same digitizer machine (AGFA CR 30-X CR).

Endodontically treated molars, as well as molars restored with crowns were excluded from the sample. Cases of teeth with carious lesions or fillings, which extend to the pulp chamber and teeth with Class V restorations were also excluded. The age of each patient was recorded on each panoramic radiograph.

The final sample was divided into six age groups. The first group (n = 161) included patients of up to 20 years of age, the second group (n = 86) ranged from ages of 20 to 29 years, the third group (n = 76) from 30 to 39 years, the fourth group (n = 72) from 40 to 49 years, the fifth group (n = 57) from 50 to 59 years and the sixth group (n = 42) included patients over 60 years of age. Each age group was subdivided into two subgroups. The first subgroup included radiographically intact teeth and the second non intact teeth (teeth with carious lesions or restorations with satisfactory marginal adaptation radiographically). Only teeth with a normal periodontal ligament contour, width and structure were included in the study.

Four distances and two angles were measured by one evaluator using certain landmarks on the panoramic radiographs. The landmarks were: The tip of the higher cusp, the mesial and distal point of the cementoenamel junction (CEJ), the most prominent mesial and distal point of the pulp chamber, the most prominent point of the pulp chamber roof and pulp chamber floor, the tip of the mesial and distal pulp horns, the top of the bifurcation, the central pit of the occlusal surface and the canal orifices as they were defined radiographically [Figure 1]. The 4 distances (A: Height of the crown, B: Distance between pulp chamber roof and floor, C: Thickness of the pulp chamber ceiling, D: Thickness of the pulp chamber floor), 2 ratios (R1: C/A, R2: D/A) and the two angles (Z1: Pulp chamber ceiling angle and Z2: Pulp chamber floor angle) are shown in Figure 1.

Cases of teeth in which the aforementioned landmarks were indistinct, were excluded.

The definition of the key landmarks, the design of the distances and angles and their measurements were carried out using the tools of EMAGO/advanced version 5.1 software, (Oral Diagnostic system, Amsterdam, The Netherlands). The module utilized by the software corresponds to pixels. Differences were examined using the independent two samples *t*-test and the *post hoc* Tukey test for multiple comparisons. The repeatability of the measurements was verified by repeating all the measurements from fifty panoramic radiographs, which were randomly selected. The difference between the two measurements was not statistically significant ($P > 0.05$).

RESULTS

All the results are shown on Table 1. The height of the crown does not present significant differences among any of the tested groups. The thickness of the pulp chamber ceiling and floor, as well as the R1 and R2 ratios, were observed to increase significantly from Group 1 to 6 ($P < 0.001$) [Figure 2]. Significant difference was not observed between the increase rates of the two walls [Figure 2]. The pulp chamber ceiling-floor distance decreased significantly from Group 1 to 6 ($P < 0.001$).

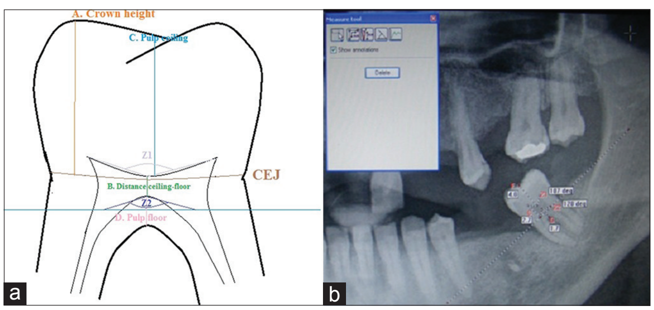

Figure 1: (a) Landmark points, distances and angles. (b) Landmark points, distances and angles measured, as shown on EMAGO/Advanced version 5.1 software

Apart from that, significant differences were identified in the thickness of the pulp chamber ceiling ($P < 0.05$), the thickness of the pulp chamber floor ($P < 0.05$) and the ceiling-floor distance ($P < 0.05$) between intact and non-intact teeth.

The pulp chamber floor angle presented significant sharpness from Group 1 to 6 ($P < 0.001$), whereas the pulp chamber ceiling angle presented significant bluntness from Group 1 to 5 and sharpness from Group 5 to 6 ($P < 0.05$) [Figure 3]. The pulp chamber floor angle was significantly different between intact and non-intact teeth ($P < 0.001$).

The pulp chamber ceiling coincided with the level of the CEJ in 98% of the mandibular molars.

DISCUSSION

To the best of our knowledge, there is no previous study in literature aiming to record the location of dentin deposition on the pulp chamber ceiling and floor. For this reason the two angles Z1 and Z2 were

Table 1: Differences in measurements of distances, angles and ratios related to age and irritating stimuli

Distances and ratios	<20 *n*=161 Mean (SD)	20-29 *n*=86 Mean (SD)	30-39 *n*=76 Mean (SD)	40-49 *n*=72 Mean (SD)	50-59 *n*=57 Mean (SD)	>60 *n*=42 Mean (SD)	ANOVA *P* value	Intact *n*=383 Mean (SD)	Non-intact *n*=111 Mean (SD)	*t* test *P* value
A. Crown height	2.99 (2.10)	2.88 (0.24)	3.08 (0.36)	2.98 (0.56)	3.12 (0.43)	3.09 (0.43)	0.867	2.94 (0.43)	3.24 (2.50)	0.208
B. Distance ceiling-floor	0.78 (0.27)	0.61 (0.30)	0.54 (0.32)	0.43 (0.20)	0.36 (0.22)	0.39 (0.37)	<0.001*	0.60 (0.31)	0.52 (0.35)	0.034*
C. Pulp chamber ceiling	2.35 (0.38)	2.46 (0.25)	2.61 (0.39)	2.56 (0.46)	2.69 (0.48)	2.77 (0.38)	<0.001*	2.49 (0.41)	2.63 (0.41)	0.001*
D. Pulp chamber floor	0.8 (0.28)	1.05 (0.17)	1.13 (0.24)	1.22 (0.26)	1.27 (0.19)	1.29 (0.25)	<0.001*	1.03 (0.32)	1.12 (0.25)	0.005*
Z1. Ceiling angle	129.07 (15.31)	130.36 (14.51)	130.11 (15.58)	132.8 (14.5)	138.49 (14.92)	132.05 (17.1)	0.004*	131.25 (13.93)	131.64 (19.76)	0.848
Z2. Floor angle	122.79 (13.2)	110.47 (11.1)	107.16 (9.75)	103.51 (9.34)	103.60 (12.56)	102.88 (10.52)	<0.001*	112.58 (14.67)	107.87 (11.47)	<0.001*
R1. C/A	0.83 (0.10)	0.86 (0.08)	0.85 (0.08)	0.86 (0.07)	0.86 (0.09)	0.90 (0.08)	<0.001*	0.85 (0.08)	0.87 (0.11)	0.073#
R2. D/A	0.29 (0.11)	0.37 (0.05)	0.37 (0.07)	0.41 (0.07)	0.41 (0.08)	0.42 (0.08)	<0.001*	0.35 (0.10)	0.37 (0.08)	0.059#

SD: Standard deviation, *Statistically significant results, #Indicative results, ANOVA: Analysis of variances

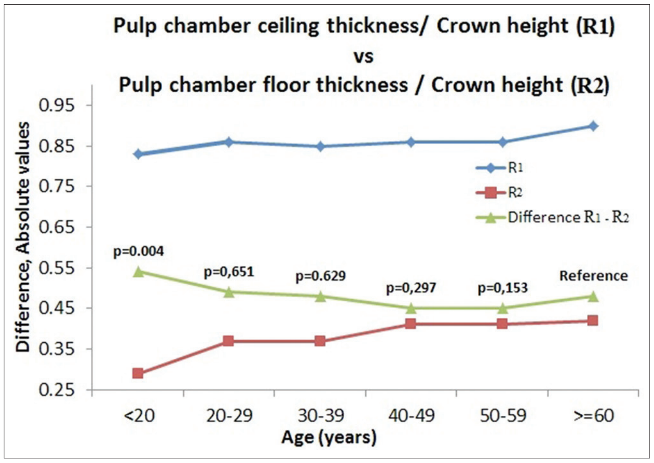

Figure 2: Pulp chamber ceiling/crown height and pulp chamber floor/crown height in relation to age

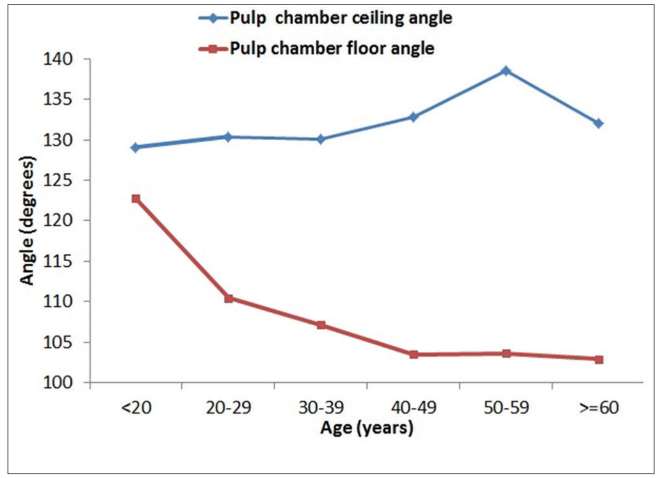

Figure 3: Angle of pulp chamber ceiling and floor in relation to age

calculated [Figure 3]. The angle of the pulp floor (Z2) presented progressive sharpness from Group 1 to Group 6. On the contrary, the angle of the pulp ceiling (Z1) presented bluntness from Group 1 to Group 5 and sharpness from Group 5 to Group 6. The changes recorded in the aforementioned angles are indicative of a continuous formation of secondary dentin in contact with the ceiling and floor of the pulp chamber. It can be assumed that the dentin formation takes place on the centre of the pulp chamber floor, sharpening the relative angle (Z2). However on the pulp chamber ceiling, dentin formation initially takes place more intensely on the pulp horns blunting the Z1 angle. The fact that the deposition of dentin takes place centrally on the pulp chamber floor may cause a false impression that there is a quantitative difference in dentin deposition between the two walls with advancing age.

All measurements were performed on panoramic radiographs. 234 panoramic radiographs and 494 mandibular molars were used in this study. The sample was divided into six groups. The last group included all patients over 60 years of age, since few radiographs were available per decade over the age of 60. Panoramic radiography presents many advantages compared with a full-mouth set of 14 periapical radiographs. It is less time-consuming, more economical and patients are exposed to a lower radiation dose.[12,13] Since a panoramic radiograph can include more than one tooth, it was easy enough to obtain a large sample size, which led to safe statistical results. Although records of all patients receiving treatment at the University of Athens Dental School include a panoramic radiograph, they do not include a full-mouth set of periapical radiographs.

The aim of the calculation of the two ratios in the present study was to eliminate all possible magnifications and deformations. All measurements were performed utilizing EMAGO/advanced version 5.1 software, which includes valuable tools for accurate and repeatable measurements. These values involve mean values of a specific tooth type, that is first and second mandibular molars.

The use of cone beam computed tomography (CBCT) imaging to evaluate the angles and distances measured in the study would probably be a valuable asset that could offer precise measurements, eliminating problems of distortion and deformation. The sagittal view of the limited CBCT image at the molar area would provide images of the highest resolution at a 1:1 ratio at an even lower effective radiation dosage.[14] A similar anatomical study utilizing computed tomography will be conducted in the future.

The pulp chamber ceiling coincided with the level of the CEJ in 98% of the mandibular molars. Our results confirm the results of a previous study which concluded that the pulp chamber roof and the level of the CEJ coincide in 98% of the maxillary and in 97% of the mandibular molars.[5] The knowledge of the level of the pulp chamber roof may facilitate the location of the pulp chamber and reduce the risk of furcal perforation.

In this study, the investigators tried to quantify the changes in the thickness of the pulp chamber walls caused by external irritating stimuli or by increasing age. The height of the crown does not present significant deviations among any of the tested groups. Consequently, the R1 and R2 ratios demonstrate possible differences in the thickness of the pulp chamber ceiling and floor respectively among the tested groups.

Both the thickness of the pulp chamber ceiling and floor, as well as the R1 and R2 ratios, were observed to increase significantly from Group 1 to Group 6. However, the increase rate of the two pulpal walls is not significantly different in any of the age Groups 2 to 6. A significant difference was only noted in Group 1 [Figure 2]. In a previous study, the amount of dentin formed was greatest on the floor and less on the ceiling of the pulp chamber.[2] Apart from that, a reduction in the height of the pulp chamber in mandibular first permanent molars by 15% has been detected which was mainly attributed to the increase in thickness of the pulp chamber floor.[10] Based on our results an assumption that the rate of dentin formation on the two walls is different or that larger amount of dentin is deposited on the pulp chamber floor cannot be supported.

The thickness of the aforementioned walls presented significant differences between intact and non-intact teeth. The differences in measurements of R1 and R2 ratios between intact and non-intact teeth were not statistically significant, but were indicative of a detectable change in thickness. Those results are also in accordance with the results of previous studies, which detect changes in pulp dimensions due to restoration procedures.[9,10]

CONCLUSION

Based on the results of this study, secondary dentin formation presents differences between the two pulpal walls with regard to the location where it takes place. Age is related to diminished pulp chamber size occlusogingivally. Although, both the ceiling and floor of the pulp chamber are gradually thickened, a difference was not observed in the rate of dentin deposition on the two aforementioned walls. External irritating stimuli also affect the pulp chamber dimensions.

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